CReSIS OIB Planning Meeting

June 29 – July 1, 2010

Prasad Gogineni, Chris Allen, Carl Leuschen,
John Paden, and William Blake

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People

Aerospace:	**Rick Hale, Emily Arnold, John Hunter, Wanbo Liu**
Radar System:	**Prasad Gogineni, Chris Allen, Carl Leuschen, Sarah Seguin, Fernando Rodriguez-Morales, John Ledford, Lei Shi, Ben Panzer, Aqsa Patel, Kyle Byers, Reid Crowe, Dennis Sundermeyer**
Data Processing:	**Ken Jezek, John Paden, Lei Shi, William Blake, Keith Lehigh, Josh Meisel, Deepananthan Dhanasekaran**

Sensors

Instrument	Measurement	Frequency (Bandwidth)	Platform	Deployment
MCoRDS	• Ice Thickness • Bed Characteristics • Bed Imaging • Internal Layering	195 MHz (30 MHz)	• DC-8 • P-3 • Twin Otter	• Fall 2009 (DC-8) • Spring 2010 (DC-8 and P-3)
Accumulation	• Internal Layering	750 MHz (300 MHz)	• P-3 • Twin Otter	• Spring 2010 (P-3)
Snow Radar	• Snow Cover • Internal Layering • Topography	4.5 MHz (4 MHz)	• DC-8 • P-3	• Spring 2009 (P-3) • Fall 2009 (DC-8) • Spring 2010 (DC-8 and P-3)
Ku-Band	• Snow Cover • Topography	14 MHz (4 MHz)	• DC-8 • P-3 • Twin Otter	• Fall 2009 (DC-8) • Spring 2010 (DC-8 and P-3)
TIDSOR	• Ice Thickness	13.5 MHz (1 MHz)	• Surface	• N/A

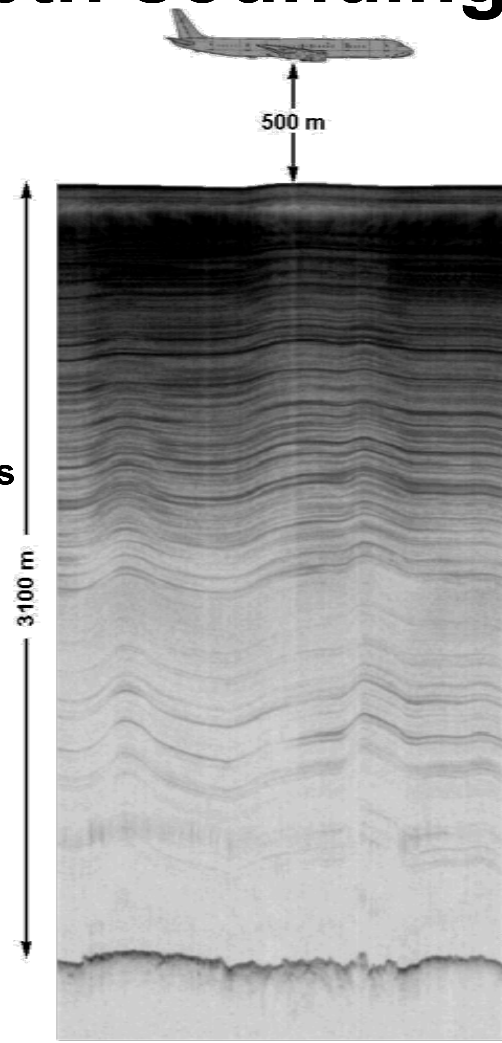
Presentations

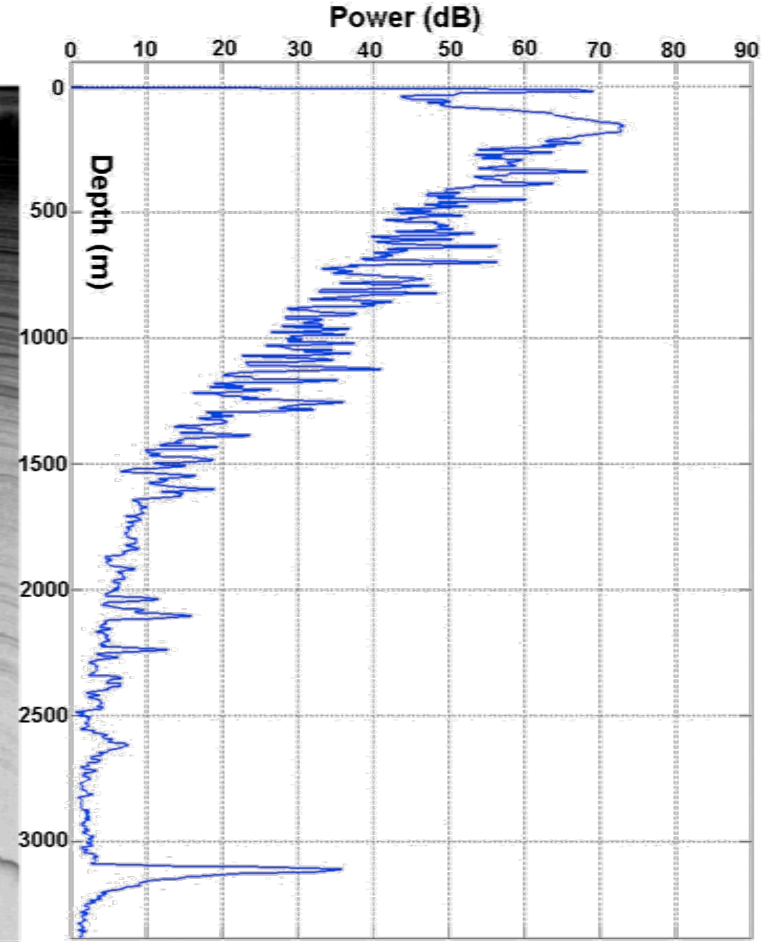
- Snow and Ku-Band Status and Results
- MCoRDS Status and Results
- MCoRDS Processing
- FMCW Processing
- MCoRDS Tomography Results
- Dual-Frequency HF Radar Sounder for Surface and Airborne Measurements

Radar depth sounding of polar ice

Multichannel Coherent Radar
<u>Depth Sounder (MCoRDS)</u>

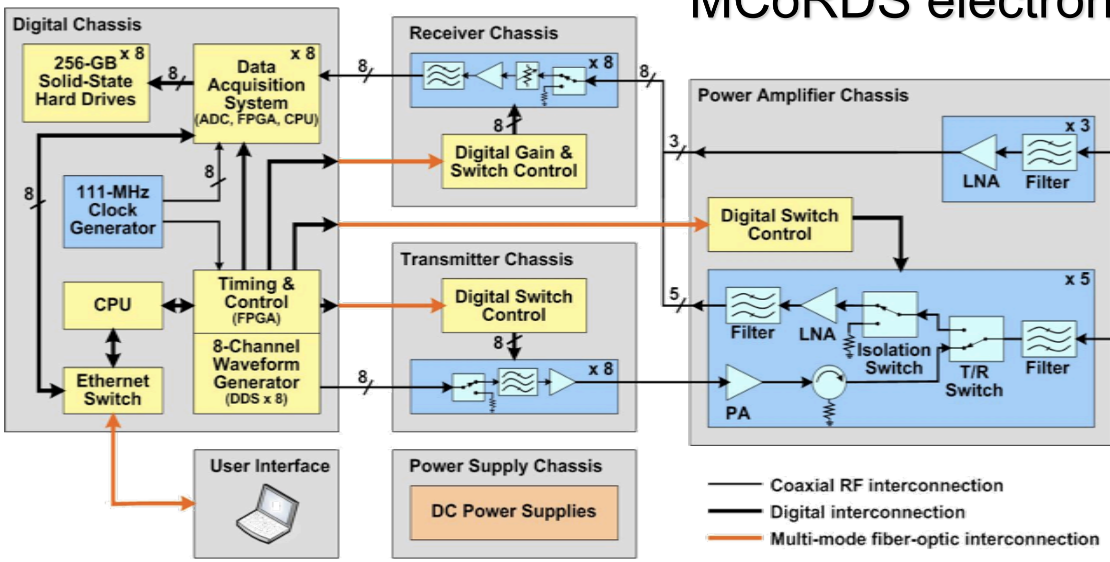
Platform:	**DC-8**
Peak transmit power:	**550 W**
Center frequency:	**195 MHz**
Waveform duration:	**1, 10, or 30 μs**
Waveform bandwidth:	**10 or 30 MHz**
PRF:	**9 kHz**
Rx noise figure:	**5 dB**
Tx/Rx antenna array:	**5 elements**
Element type:	**λ/4 dipole**



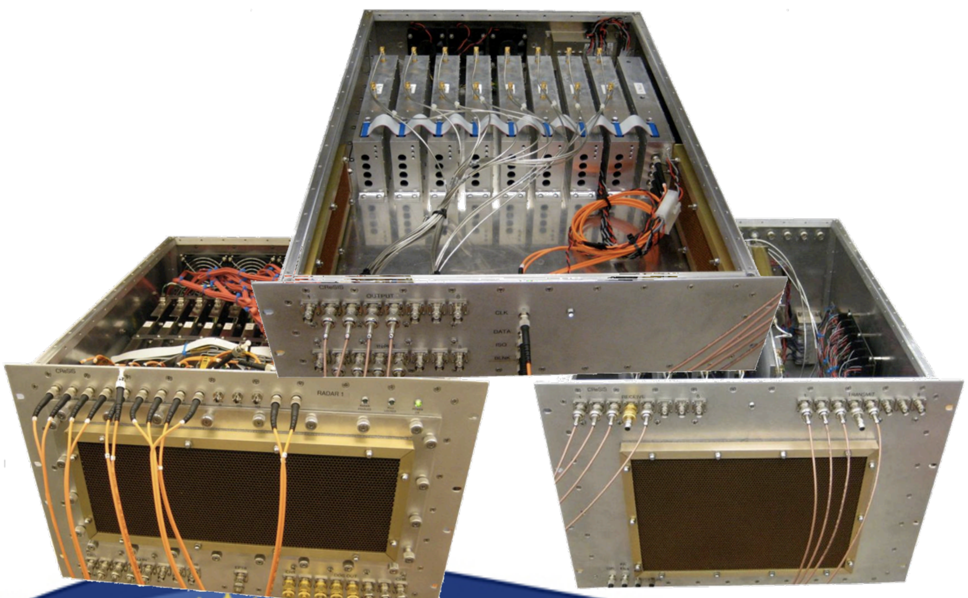


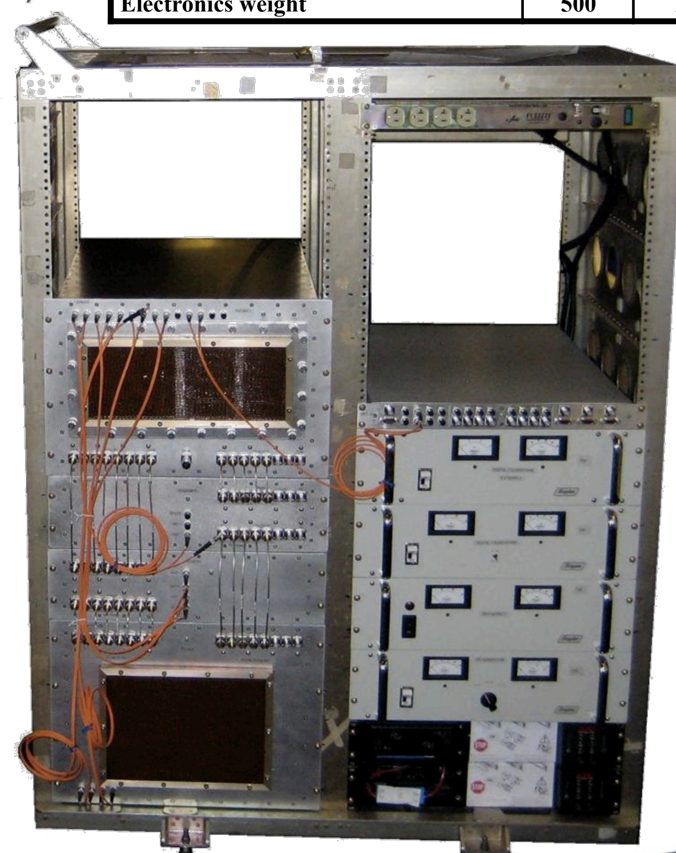
Sensor hardware for OIB DC-8

MCoRDS electronics



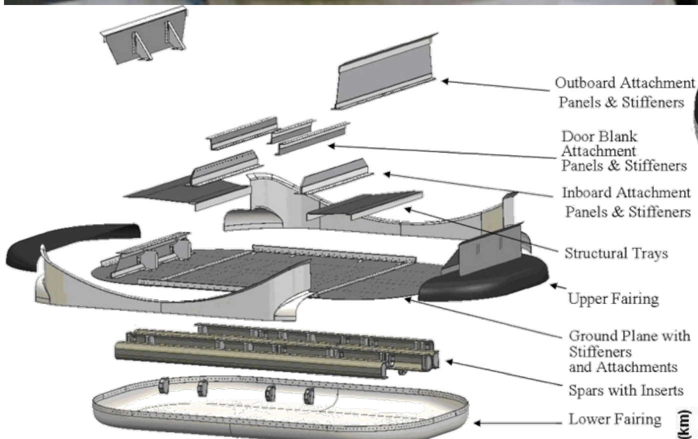
Parameter	*Value*	*Units*
Hardware presums	16	
Digitizer sample rate (per channel)	111	MSa/s
Receive vector length	10,000	samples
Recording data rate (per channel)	21	MB/s
Number of receive channels	8	
Solid-state drive capacity (per channel)	256	GB
On-board data storage capacity	2	TB
Electronics weight	500	lbs

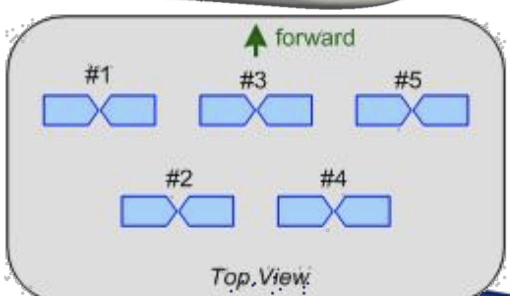


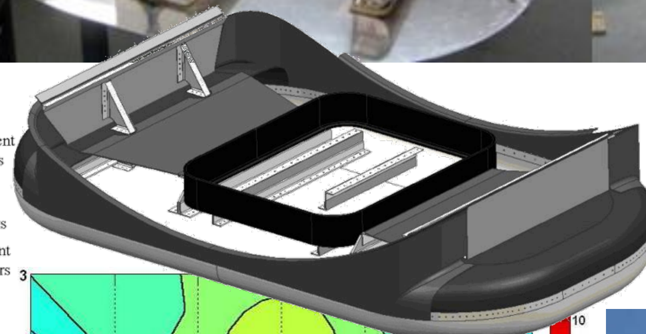


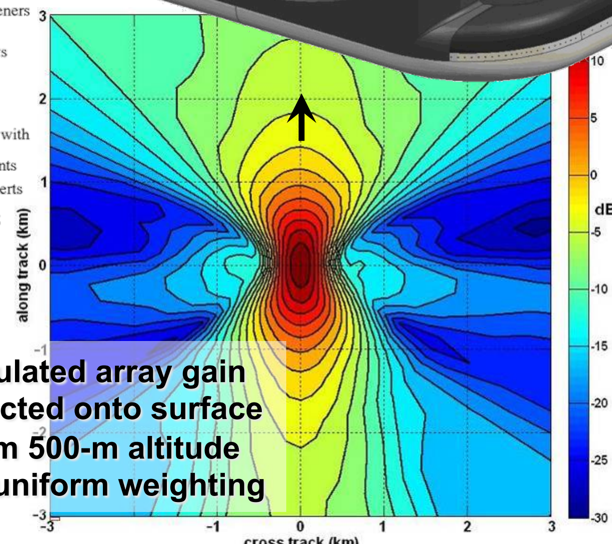
Sensor hardware for OIB DC-8

MCoRDS antenna array and fairing hardware







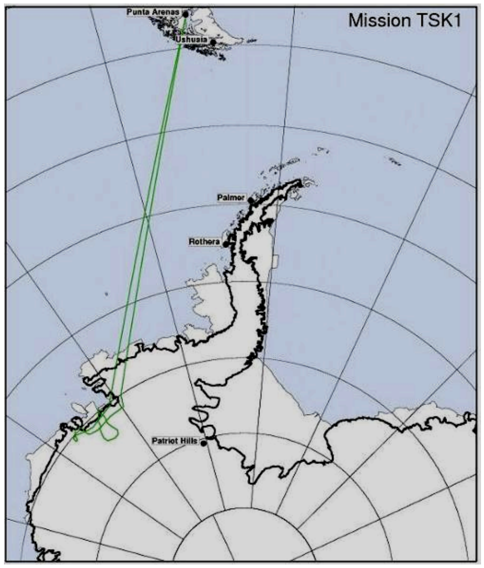


Simulated array gain projected onto surface from 500-m altitude with uniform weighting

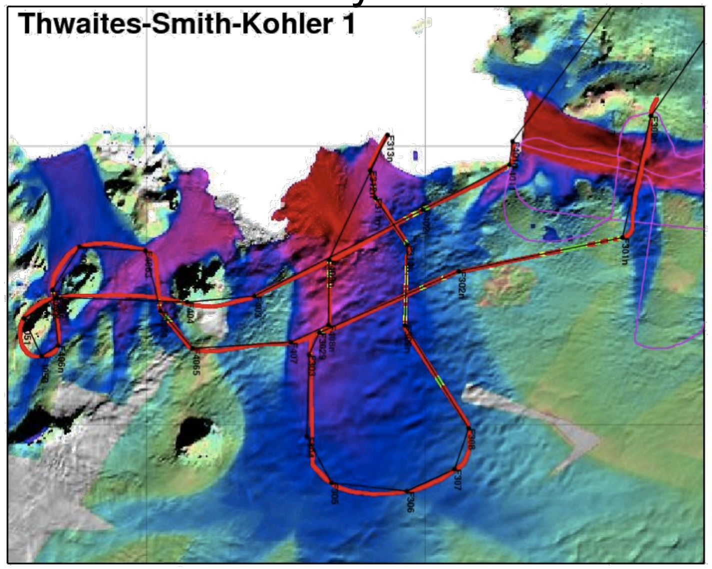
5-element staggered collinear array
Ground plane dimensions: 2.5 x 4.5 m
Assembled weight (est.): 425 lbs
Added drag (simulated): 1.3%

Example data from 02-Nov-09 Flight #12 TSK1 Mission

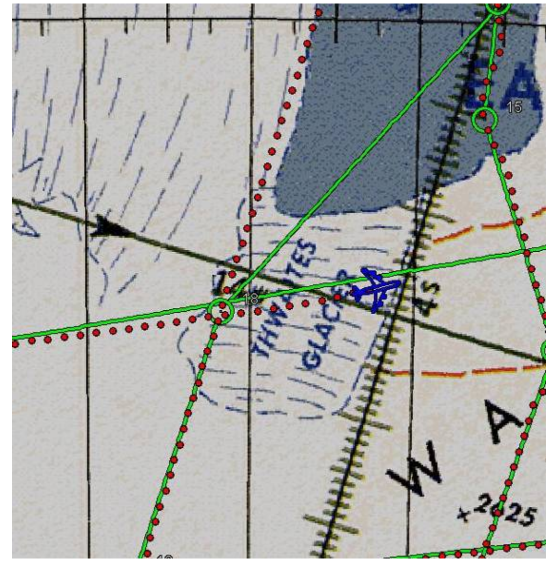
Mission Overview

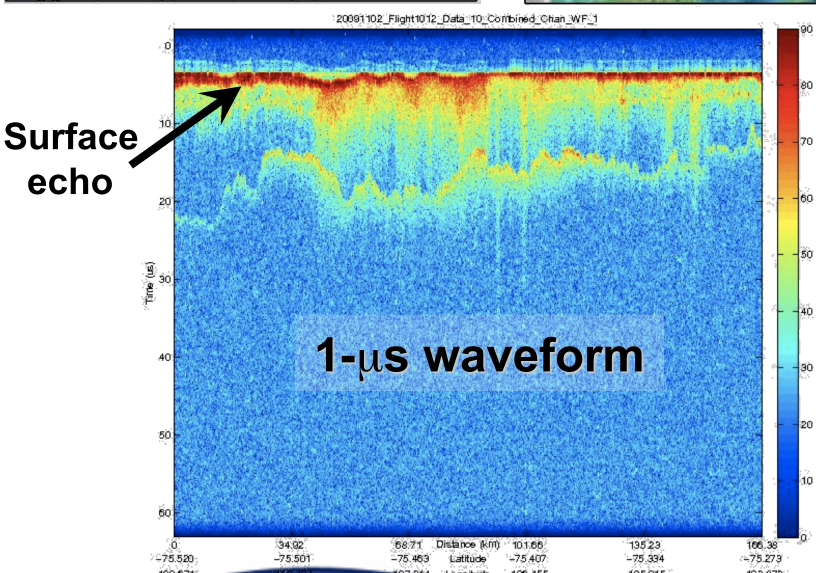


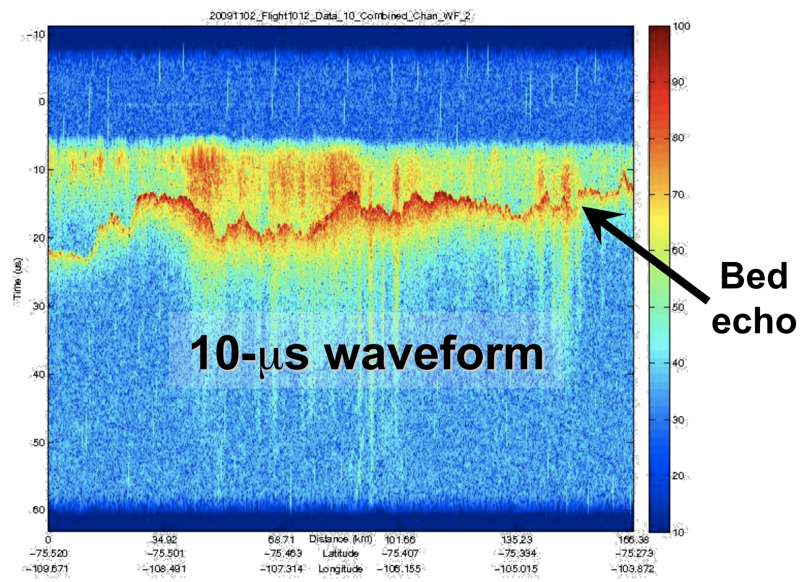
Survey Details



Falcon View Map







MCoRDS data summary and status

Flight #	Date	Survey Area	Data Set Volume (GB)
1	10/16/2009	GETZ	**1256**
2	10/18/2009	TSK2	**1230**
3	10/20/2009	Pine Island (High Alt)	**1016**
4	10/21/2009	SeaIce2	
5	10/24/2009	SeaIce1	
6	10/25/2009	86° Arc (High Alt)	**1280**
7	10/27/2009	PIG2	**1684**
8	10/28/2009	TSK3	**616**
9	10/29/2009	PIG1	**1416**
10	10/30/2009	SeaIce3	
11	10/31/2009	PEN2	**1360**
12	11/2/2009	TSK1	**1216**
13	11/3/2009	PEN1	**1280**
14	11/4/2009	PEN3	**2000**
15	11/5/2009	Peninsula (High Alt)	**1624**
16	11/7/2009	PIG3	**1392**
17	11/9/2009	PIG4	**1184**
18	11/12/2009	ABBOTT	**980**
19	11/15/2009	PEN4	**1232**
20	11/16/2009	PEN5	**1552**
21	11/21/2009	TSK4	**912**

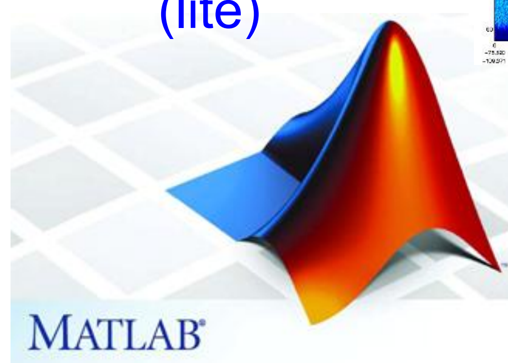
PIG: Pine Island; TSK: Thwaites, Smith, Kohler

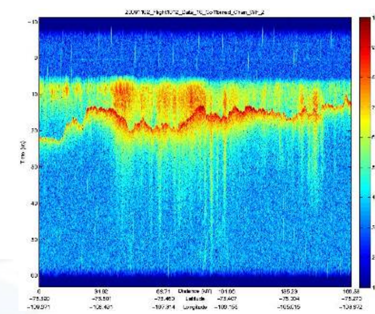
All low-altitude data sets processed using basic algorithm, surface and bed echoes hand picked, and resulting thickness values have been posted. Data will be reprocessed using f-k process and more automated bed-picking process.

MCoRDS – data processing

Capture radar echoes → 16x coherent integrations (hardware) → Write to hard drives → 100x coherent integrations (Matlab) → Pulse compress (Matlab) → Generate echograms (Matlab)

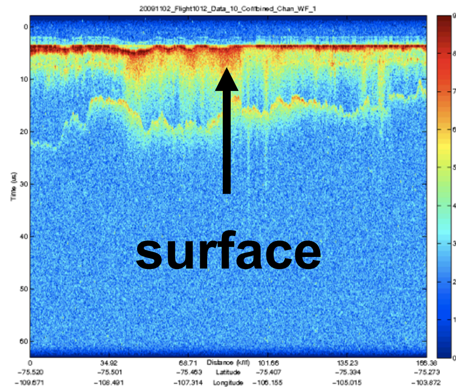
CSARP
(lite)





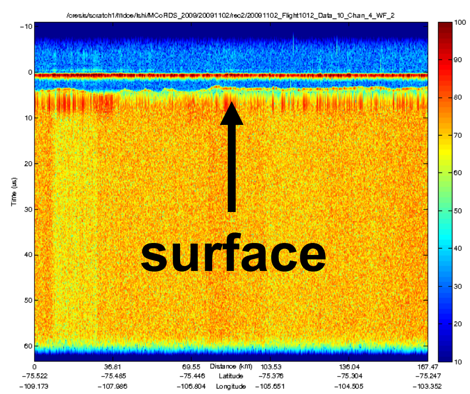
MCoRDS – data processing

Waveform 1

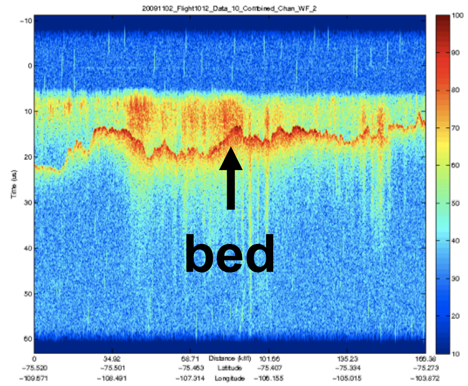


or

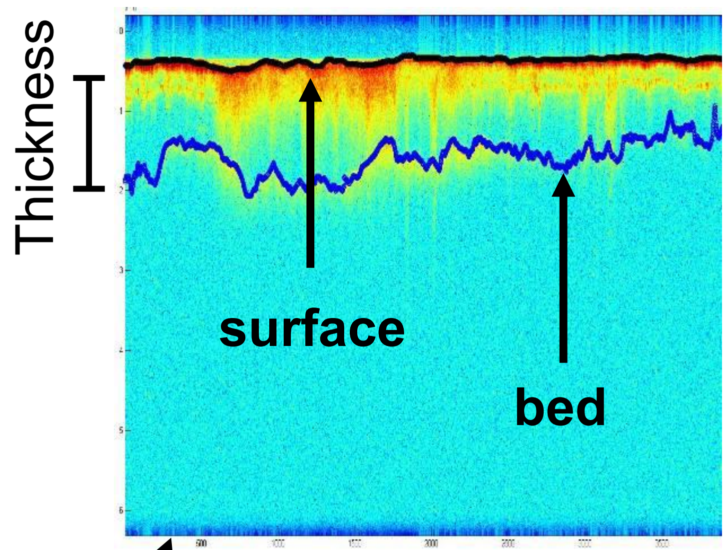
EMI Channel

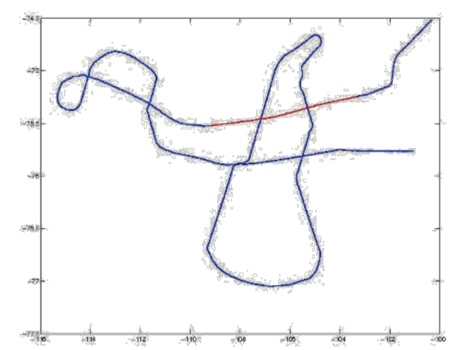


Waveform 2



Layer Tracing

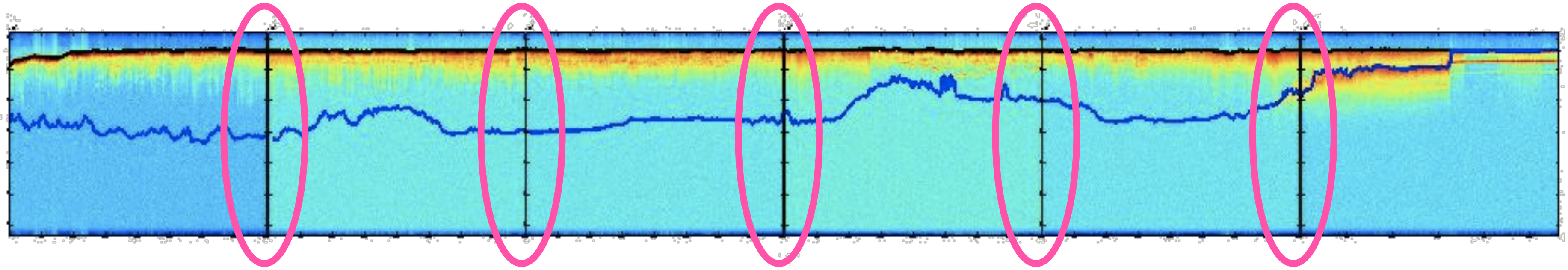


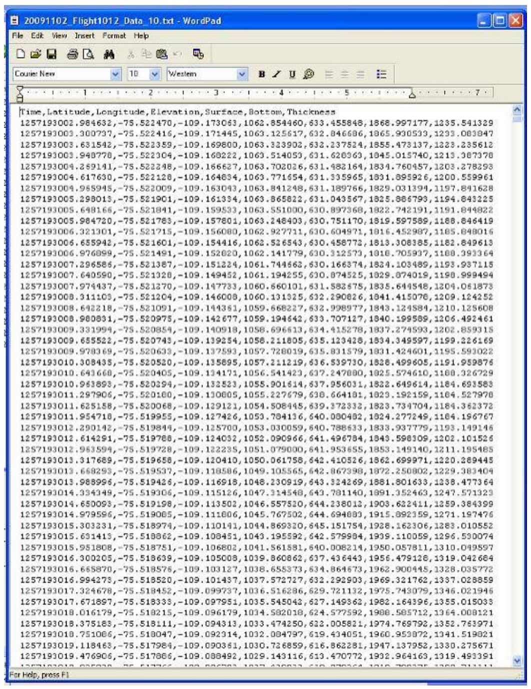


Flight Path

Echogram represented in red

Continuity Check

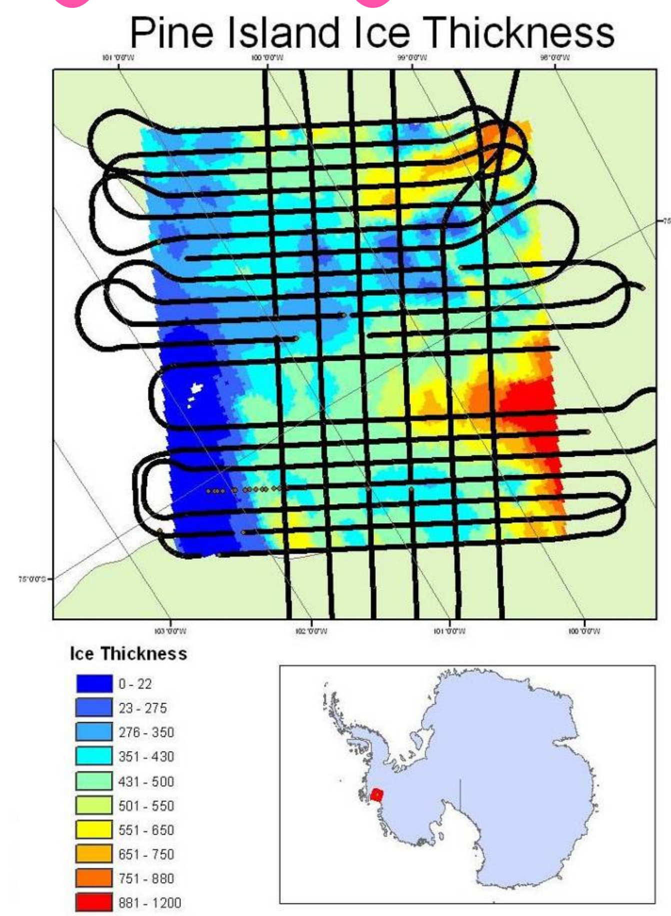




Generate Text (.txt) files with:

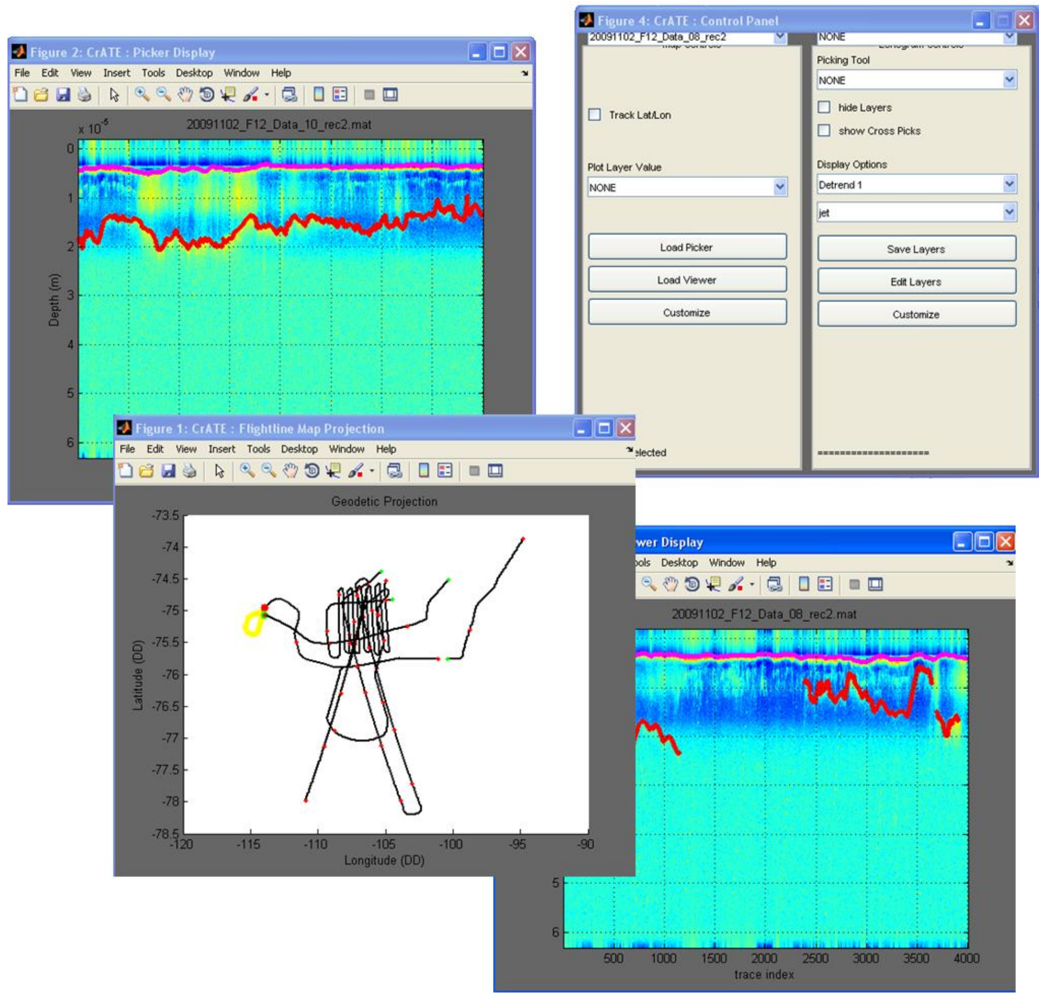
- Time
- Latitude
- Longitude
- Thickness

Disregard:
Elevation, Surface, Bottom



Crossover areas

- Newly developed layer tracing software “Crate 4”
- Load and compare two echograms (across multiple missions if needed)
- Fix a crossover inconsistency on the spot
- A separate crossover error detection program is being developed.
- Ohio State University using ArcGIS for detecting inconsistencies in processed data



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Crossover areas

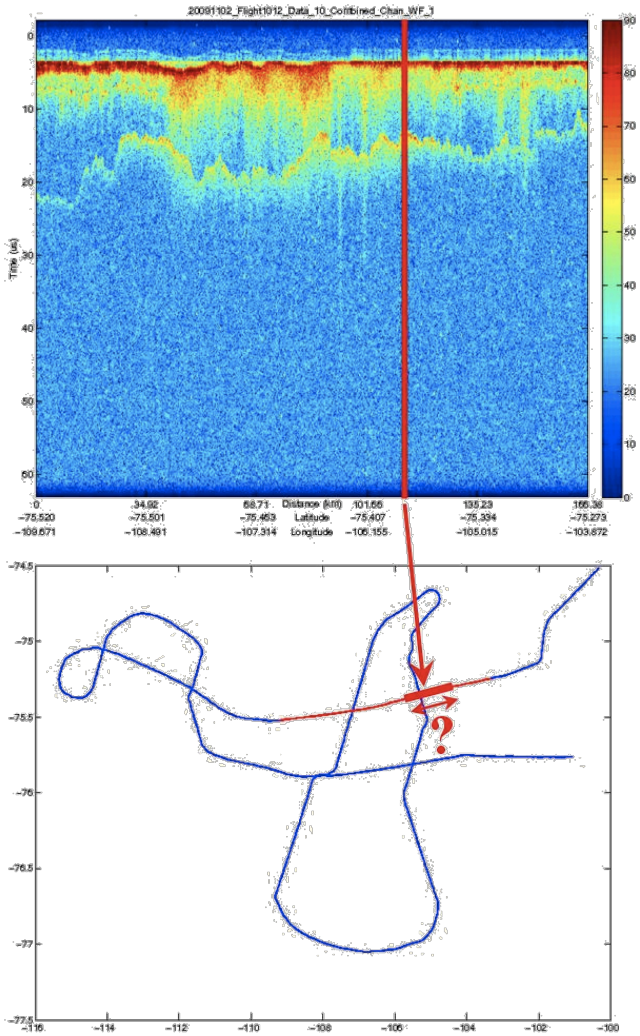
Variable time-stamp latency (about 2 seconds) contributes to crossover discrepancies

Multiple potential causes for this latency (in-flight data server, radar time-stamp manager)

Net result is location uncertainty along flight path which contributes to crossover discrepancies in measured ice thickness

Short-term solution, attempt to remove this unknown latency

Long-term solution may involve direct access to GPS receiver output and refined radar time-stamp management



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Data acquisition issues

Flight 7 (10/27/2009) PIG and Flight 8 (10/28/2009) TSK

Radar Configuration File		Radar Controller Error	Effects of Error
WAVEFORM 1			Data rates were too high for recording
Waveform Duration	10us	Used for Waveform 1	
Record Length	70us	These times used for both waveforms (1 and 2).	Recording began too late for surface returns to be captured
Record Start	23us		
WAVEFORM 2			
Waveform Duration	1us	Used for Waveform 2	Result – no surface echo for ice thickness measurement
Record Length	25us	Not used	
Record Start	9us		

Data acquisition issues

Flight 7 (10/27/2009) and 8 (10/28/2009)

Capture radar echoes → 16x coherent integrations (hardware) → Write to hard drives → . . .

See diagram from earlier slide

16x coherent integrations (hardware) ↓ High integration channel 100x presums → 

Also known as:
- Quicklook
- Scrolling Echogram

High Integration Channel Data

- Sampled every 1 / 62.5 hard drive writes
- Stored on laptop computer
- Useable data recorded
- No surface echo (uses same record window)

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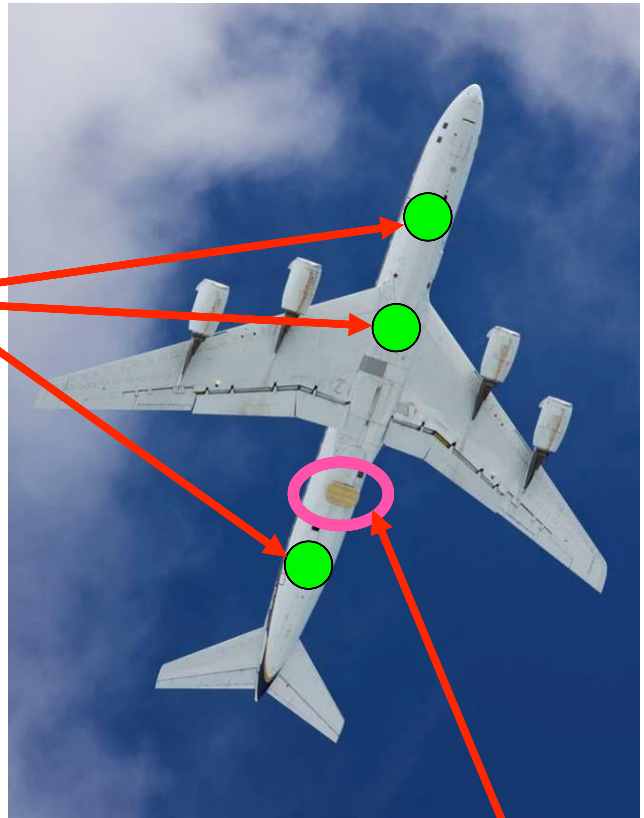
EMI vs radar antennas

EMI antennas (x3)



Radar antenna array (x5)

- EMI-monitoring antennas located inside cabin
- EMI channel data often used for surface tracing
- Radar channel data used for bed tracing
- Cable lengths are different
- Ice thickness adjustments made to reflect the difference in cable lengths.

Process for ice thickness DEM generation

Processed airborne radar data

↓

Conversion of lat, long to South Pole stereographic projection

↓

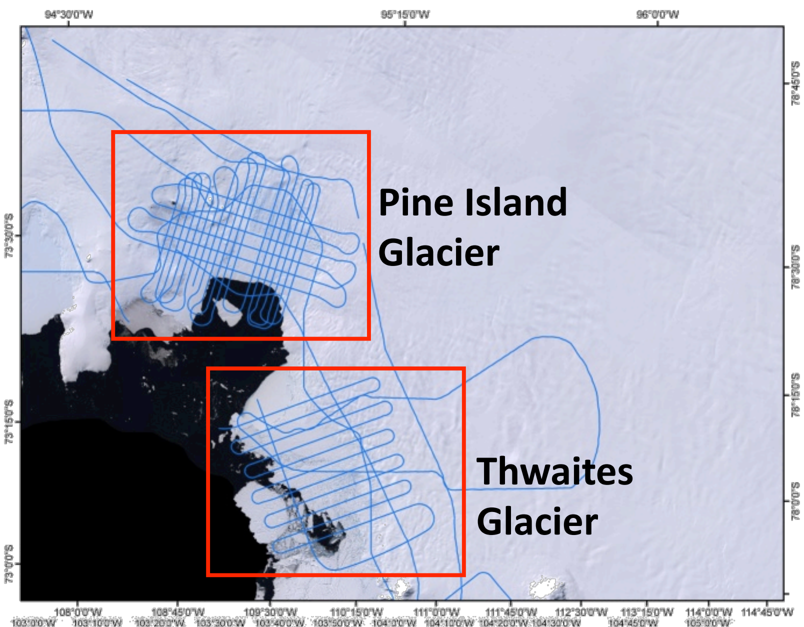
Joining all flight paths

↓

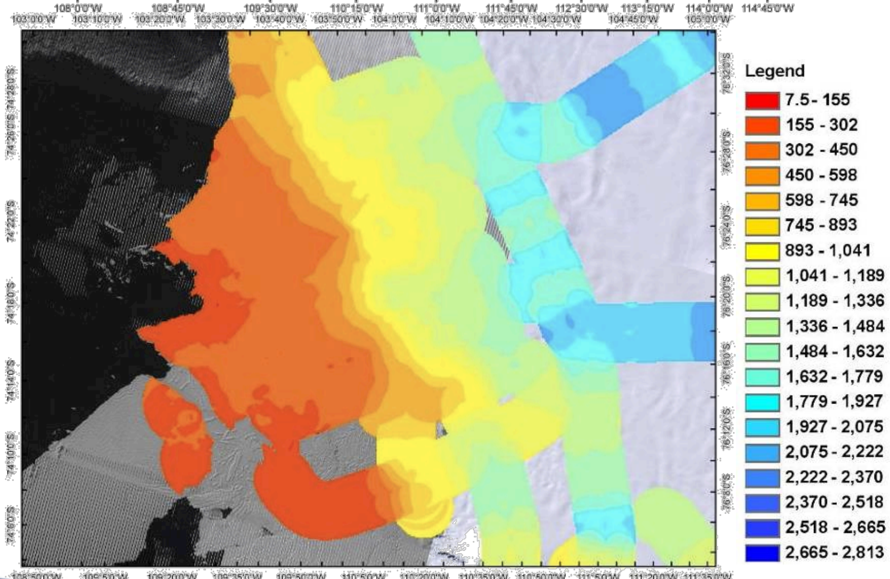
Plotting in GIS environment

↓

Spatial interpolation of ice thickness values



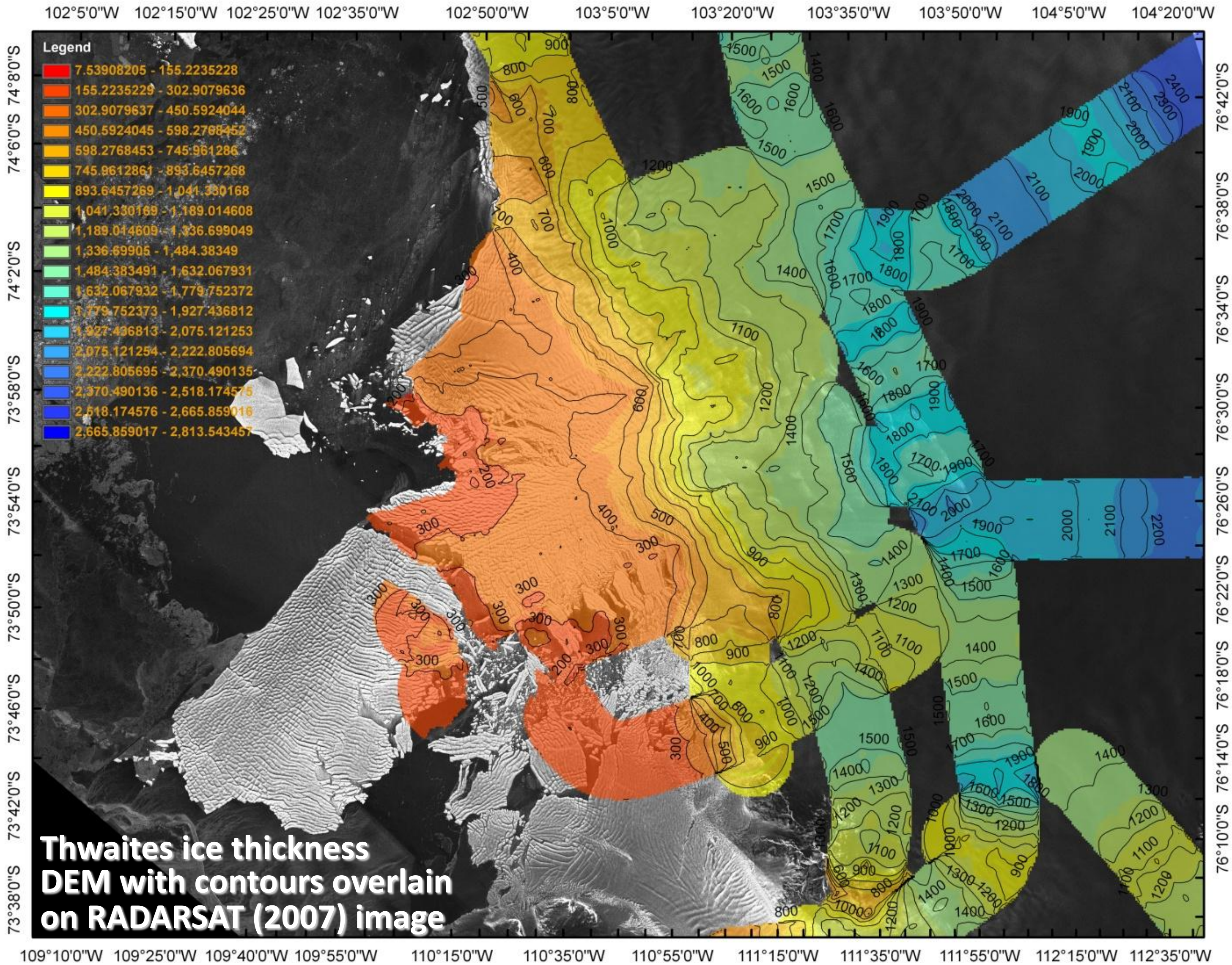
Flight path over Pine Island and Thwaites Glaciers



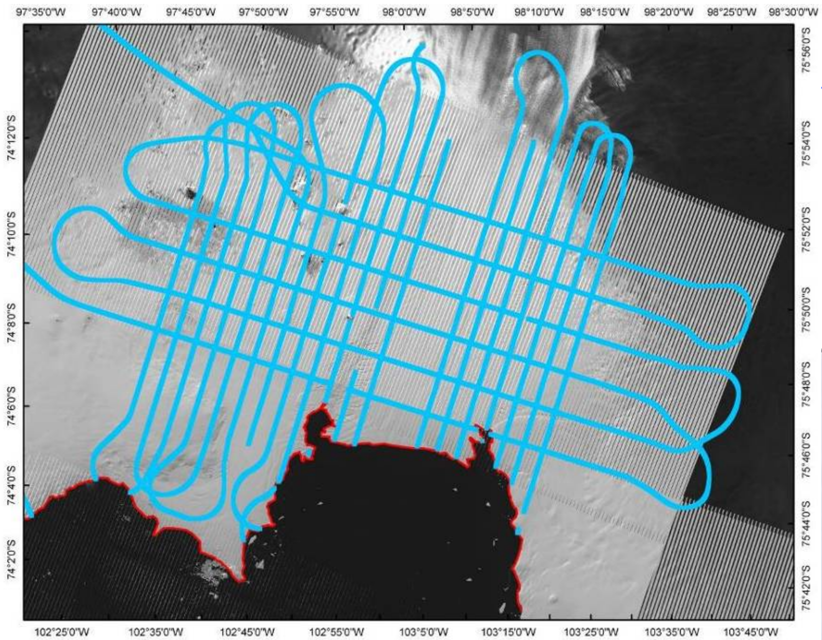
Linear IDW interpolated (10-km search radius) ice thickness DEM over Thwaites Glacier

IDW = inverse distance weighted

Thwaites ice thickness DEM

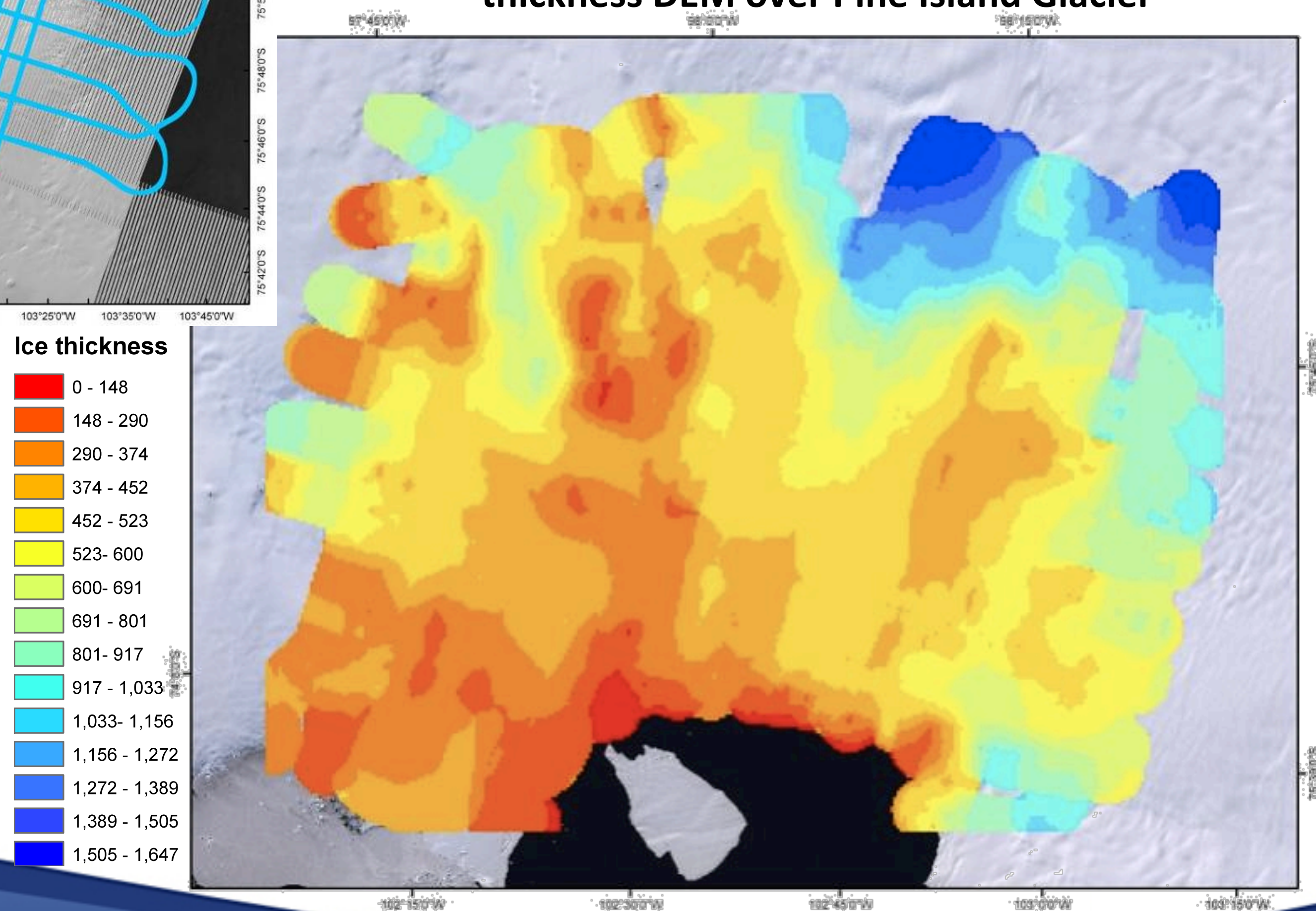


Pine Island ice thickness DEM



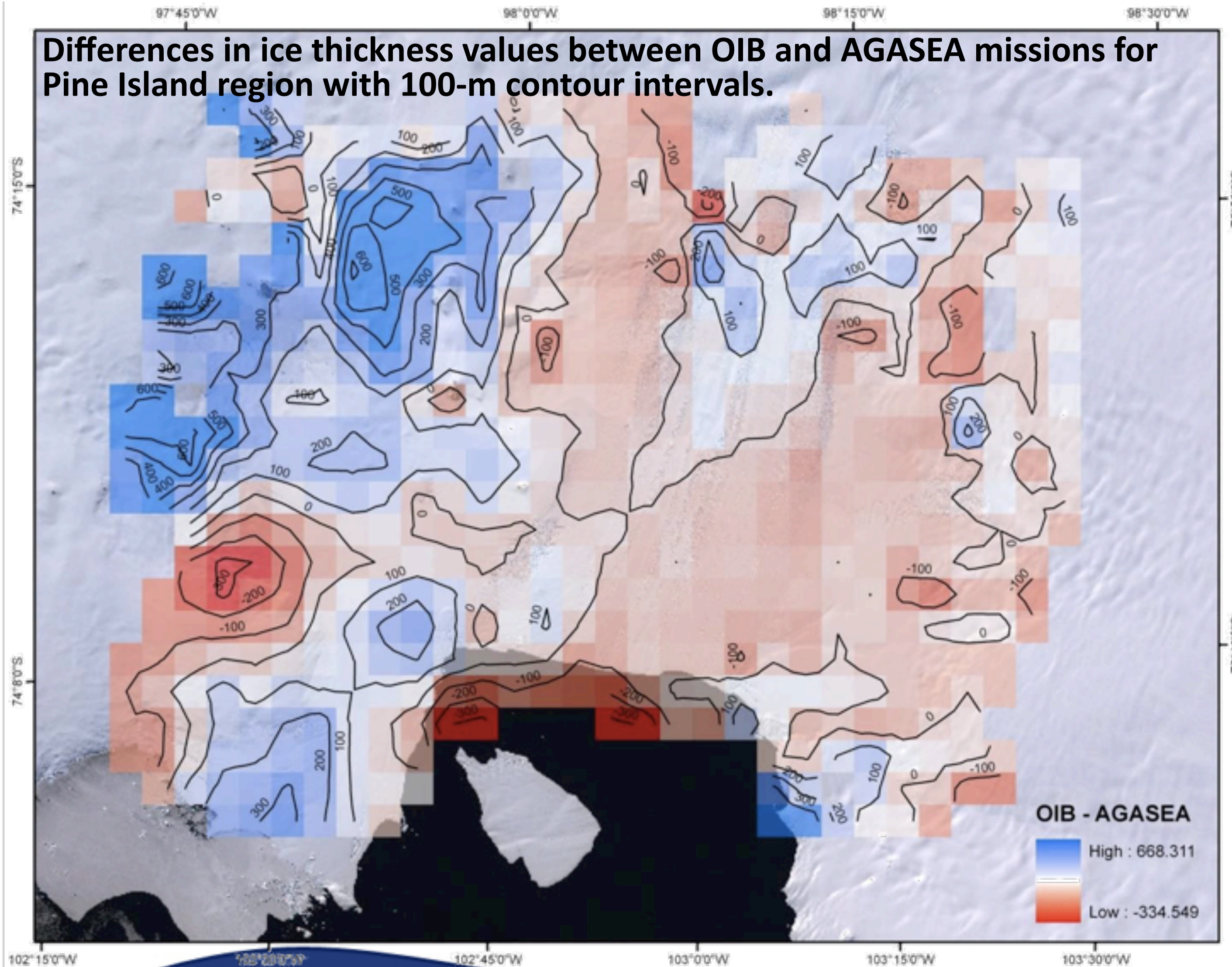
Flight path over Pine Island Glacier

Linear IDW interpolated (10-km search radius) ice thickness DEM over Pine Island Glacier



OIB ice thickness compared with AGASEA

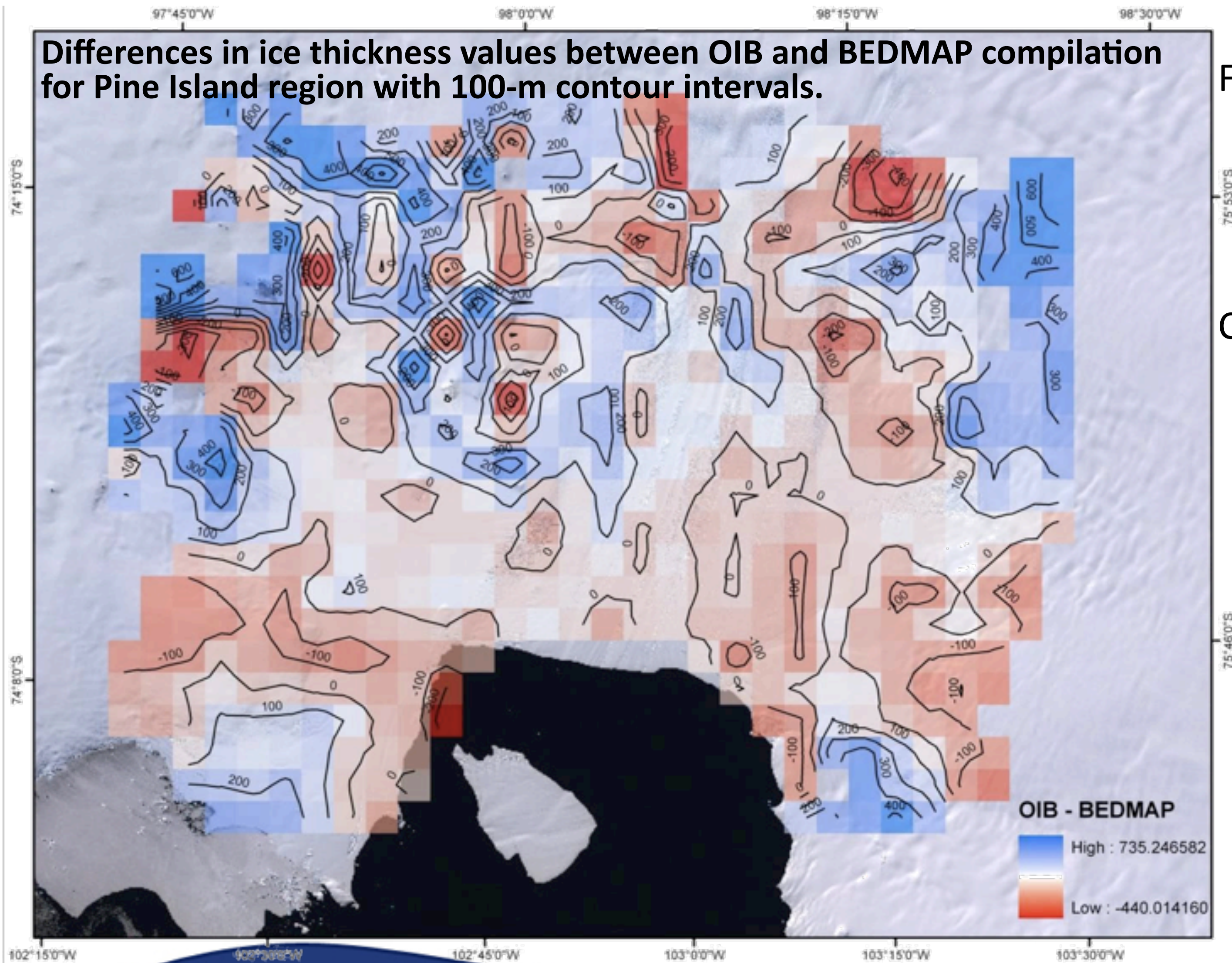
(*Holt et al.*, 2006)



Excellent agreement on downstream portion of ice shelf. The contours are smooth and widely spaced over the Pine Island ice tongue and glacier.

Difference in upper reaches of data set suggest possible ice thinning.

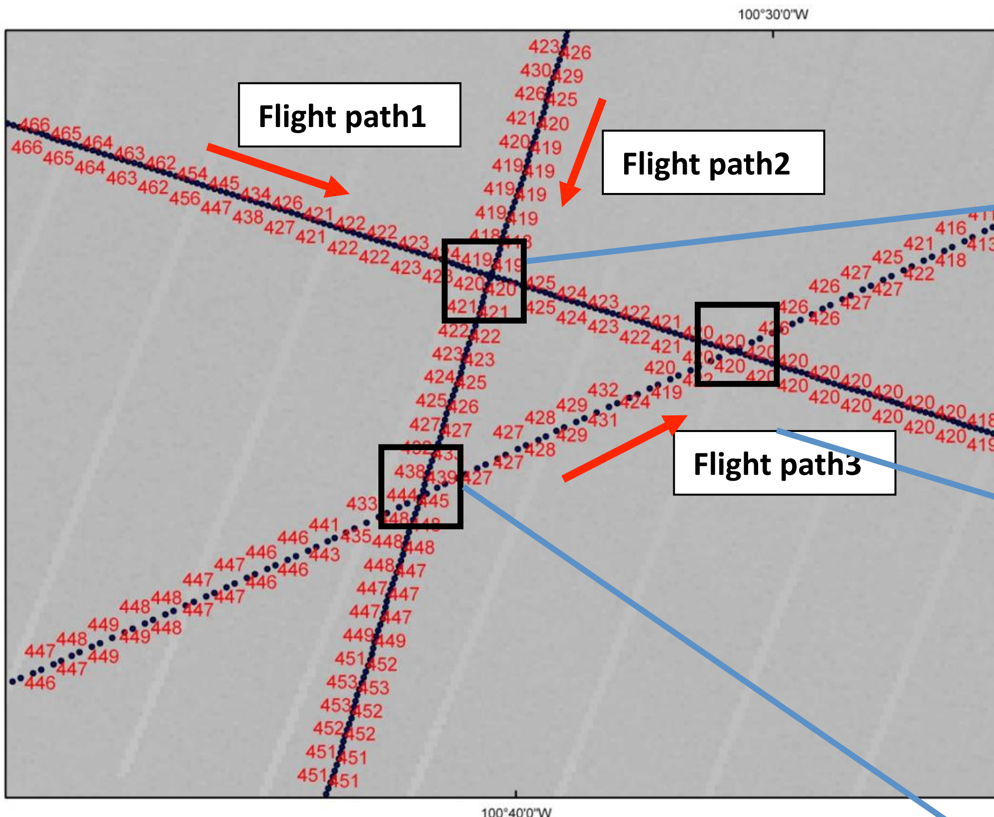
OIB ice thickness compared with BEDMAP
(*Lythe et al.*, 2000)



Favorable agreement over the downstream area of Pine Island Glacier.

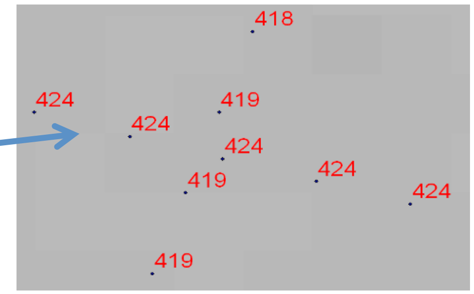
Comparison indicates possible thinning in upper reaches of the data set.

Crossover differences within OIB flight paths

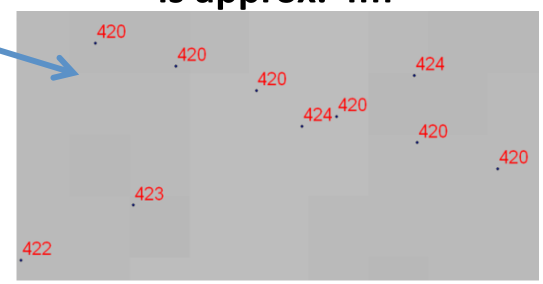


Date of flight path 1 : 20091107
Date of flight path 2 : 20091107
Date of flight path 3 : 20091027

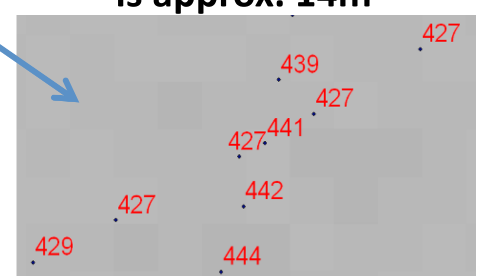
Diff. between path1 and path2 is approx. 5m

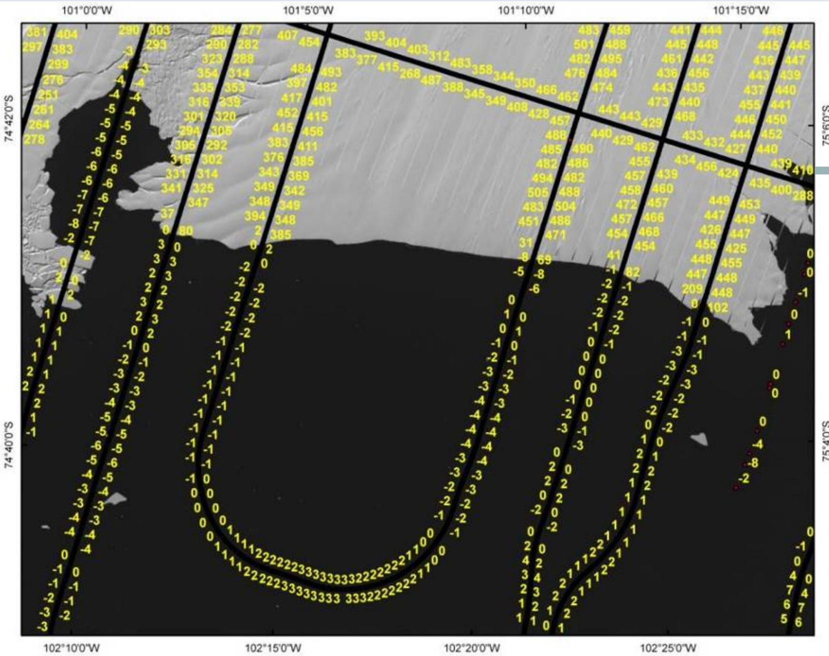


Diff. between path1 and path3 is approx. 4m

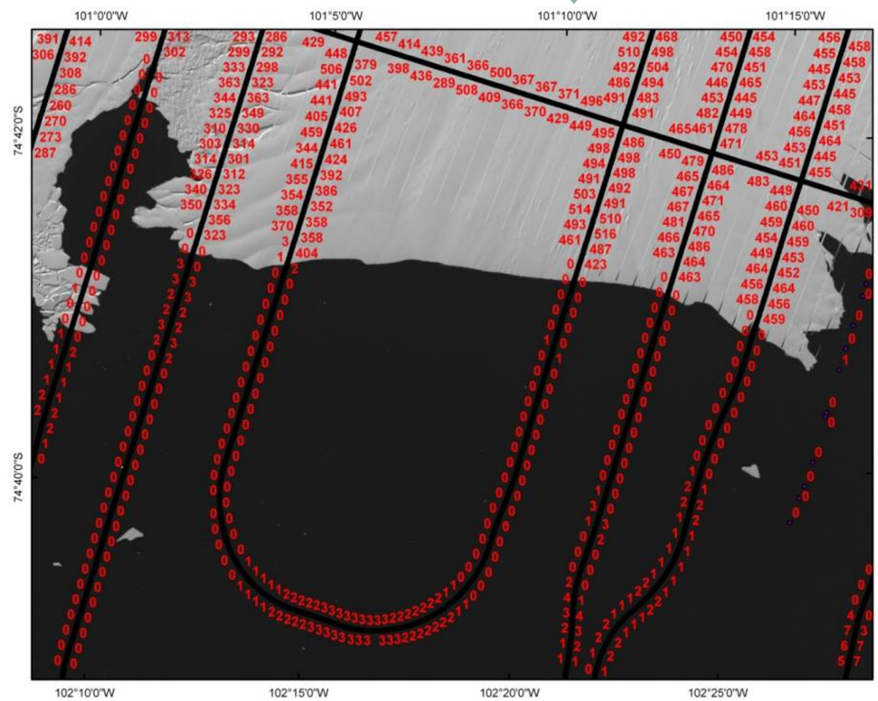


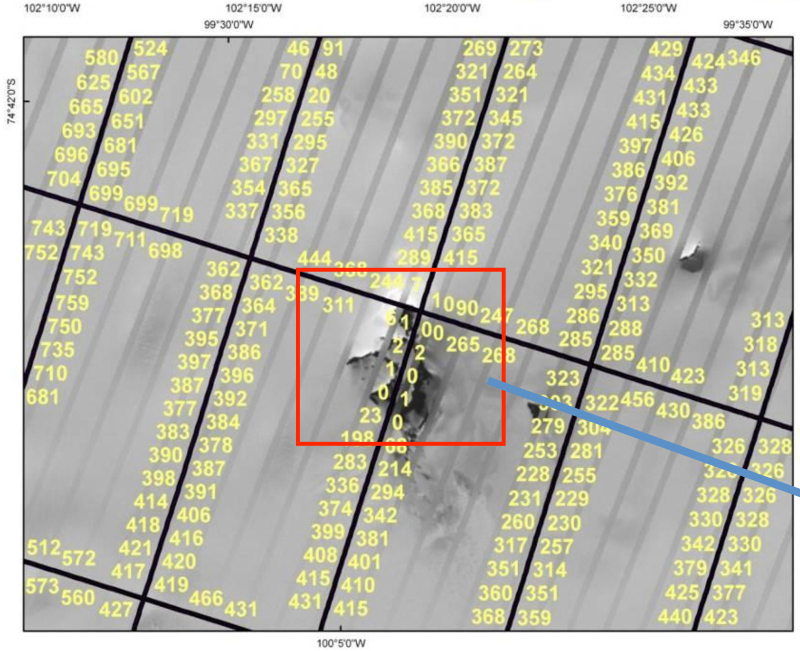
Diff. between path2 and path3 is approx. 14m





After correcting for cable length differences and surface/bed picking





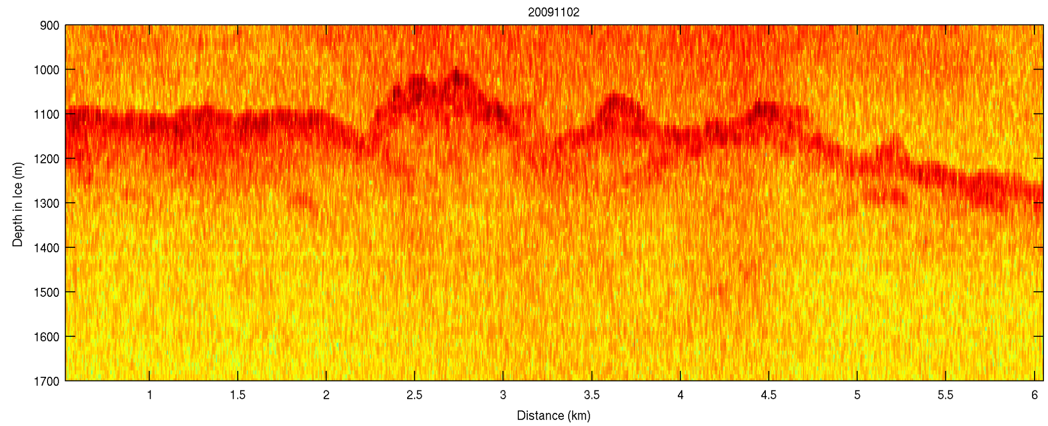
Reasonable thickness values over the rocky outcrop area, as it remains close to zero.

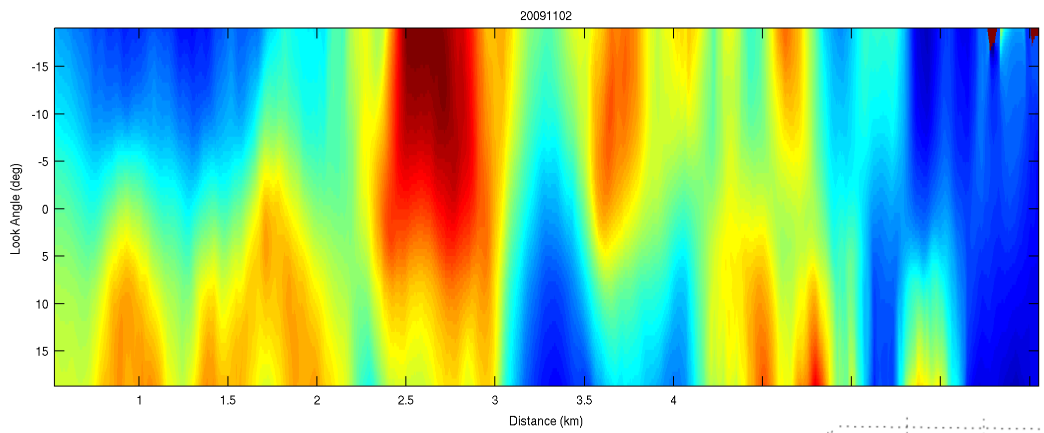
Summary

- Successfully sounded Antarctic glaciers and ice shelves in 2009
- Pine Island and Thwaites surveys show good data quality
- Identified areas for improving system performance
  - Radar operating software upgraded
  - Time-stamp latency issues identified
  - Potential for expanding bandwidth to 30 MHz
  - Power amplifier chassis upgraded to support P-3 missions
- More efficient processing algorithms developed
- Advanced processing in development that will reveal latent features

Future work

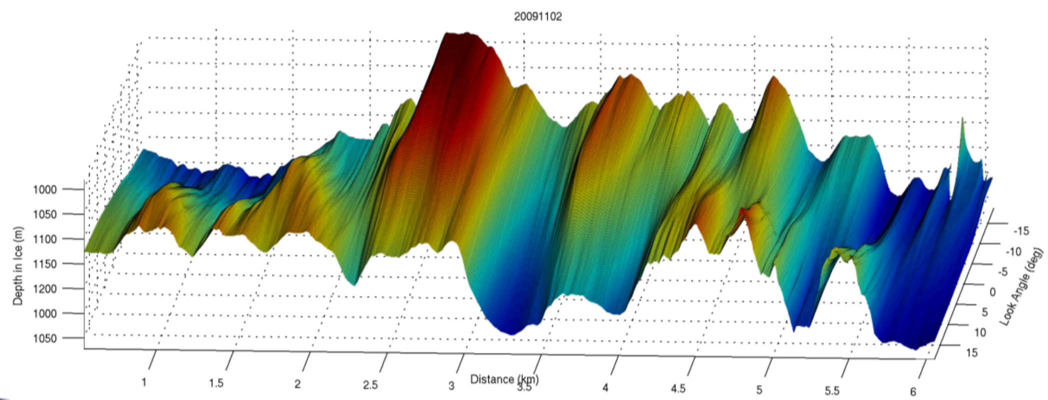
f-k migration processing data from each channel





tomographic processing across the 5 receive channels provides angle-of-arrival information

project angle-of-arrival into basal topography
(preliminary results, subject to change)



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WHERE DISCOVERIES BEGIN

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